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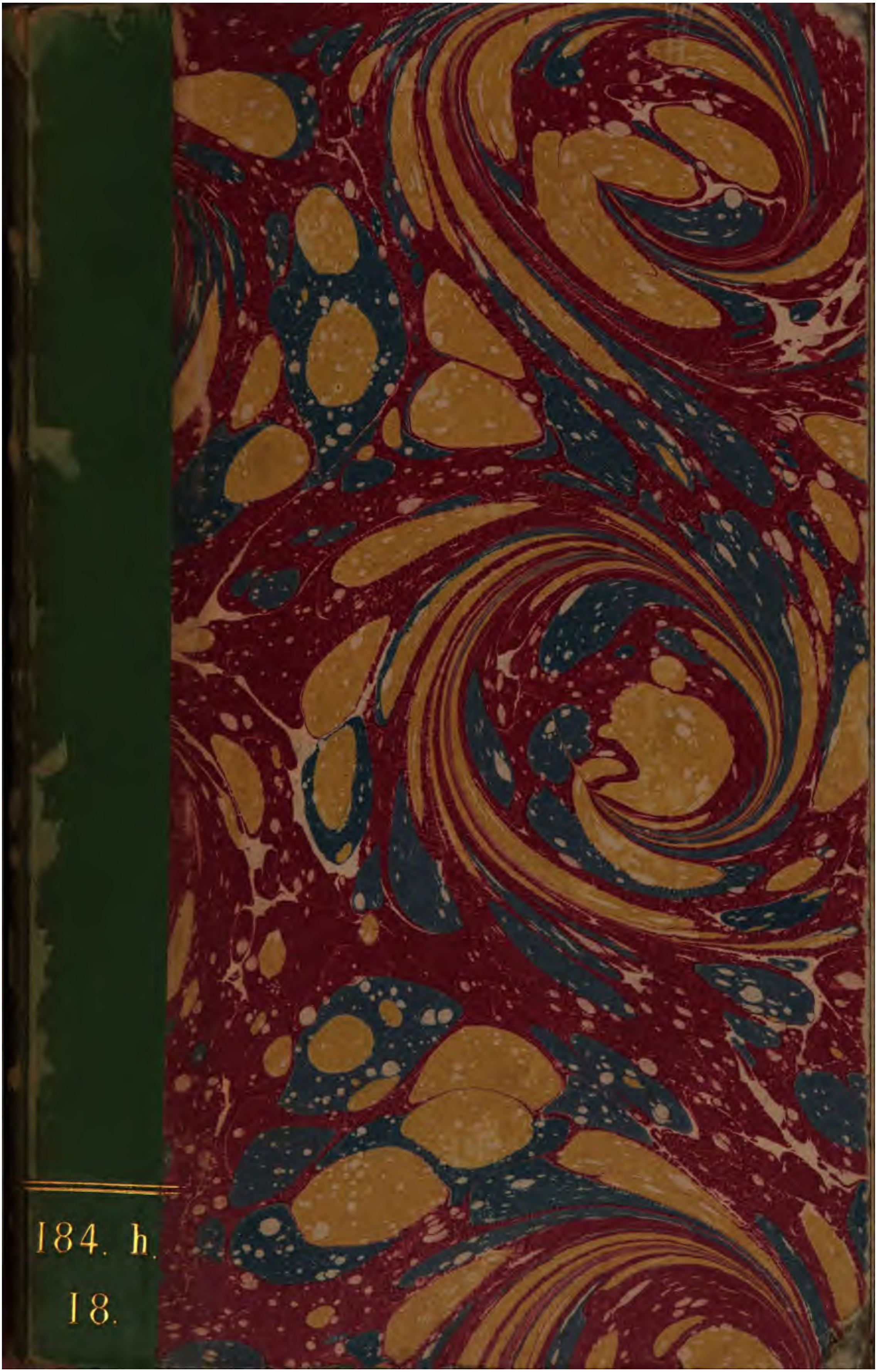

184. h.
18.

A NEW AND EASY METHOD

OF

FINDING THE TIME AT SEA,

AND FOR ASCERTAINING

THE VARIATION OF THE COMPASS;

All requiring no Calculation except a little Addition or Subtraction, and independent of knowing either Latitude or Longitude within two degrees.

BY

JAMES HAY, C.E.,
AUTHOR OF A "SYSTEM OF MECHANICS," &C.

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EDINBURGH:
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NEW AND EASY METHOD

OF

FINDING THE TIME AT SEA,

AND FOR

ASCERTAINING THE VARIATION OF THE COMPASS.

Art. I.—This important problem is founded upon the following principles. That the positions and distances of the fixed stars amongst themselves are ever the same. That their positions, with respect to the horizon of an observer, are ever changing. That a great circle of the sphere may be conceived to pass through any two fixed stars taken separately. That the plane of this great circle passes through the earth's centre, and intersects the equator in two points at 180 degrees apart, and these two fixed points making a determinate and fixed angle with the equator. In all parts of the world, as far north or south as the great circles extend, the two stars will appear to an observer in a vertical, or line perpendicular to the horizon, at least once in 24 sidereal hours; and in latitudes, where the stars do not set, they will so appear twice in that interval, but inverted. The two points in the equator, intersected by the great circle or vertical, may be called the Equatorial Nodes of the Vertical, or simply the Nodes. These points are the zero from which all arcs are to be measured, and the equator the base on which they are measured.

From the above principles, and the data given in the "Nautical Almanac," the following Rules and Tables have been constructed in the following manner.

II. Let EQ, Fig. 1 and 2, represent the Equator; P either Pole; VZ a Vertical circle passing through two known stars Ss; Z the Zenith or place of an observer situated for an instant in the plane of the vertical circle; and A the Node or point in the equator intersected by the vertical. Then SB and sC are the declinations of the stars, and BC the difference of their right ascension.

To Determine the Right Ascension of the Point A, or Node.

Case 1. Fig. 1.—When the stars are on opposite sides of the equator.

As the sine of the sum of the declinations SB+sC : is to the sine of their difference SB∽sC : : so is the tangent of half the sum of the bases $\frac{BA+CA}{2}$ $\left(\frac{BC}{2}\right)$: to the tangent of half their difference $\frac{BA \backsim CA}{2}$.

Case 2. Fig. 2.—When the stars are both on the same side of the equator.

As the sine of the difference of declination SB∽sC : is to the sine of their sum SB+sC : : so is the tangent of half the difference of the bases $\frac{BC}{2}$: to tangent of half their sum $\frac{AB+AC}{2}$.

In both cases the half difference added to the half sum gives the greater base, whether AB or AC, and subtracted gives the less. The right ascension of the point A is therefore known.

III. To find the angle of intersection of the node A with the equator, as sine of AB : is to Rad. : : Tan. SB : Tan. A.

The same Principle applied to Stars having equal Altitudes.

IV. When two stars are observed to have equal altitudes, the observer is in the plane of a vertical circle, which bisects the subtense of the stars at right angles.

Fig. 3.—Let Z be the Zenith of the observer, ZN the Vertical, Ss two Stars having equal altitudes. The subtense Ss being parallel to the horizon, it must be perpendicular to the vertical

ZN; A is therefore a right angle. The stars having equal altitudes, their zenith distances are also equal. In the two right angled triangles SAZ, sAZ the sides SA, sA are equal, and the side ZA is common to both. The triangles are therefore equal and similar. Ss is therefore bisected at right angles in A.

Fig. 4 and 5.—Let the letters represent the same as in Fig. 2 and 3, and let VND′ be a Vertical bisecting the subtense of the stars Ss in D at right angles. Find the point A and its angle, made with the equator as in the vertical stars, Art. II. In the right-angled triangle ABS, there are given angle A and side AB to find the hypotenuse AS. In the right-angled triangle ACs, are given angle A and side AC to find the hypotenuse As. Then, when the stars are both on the same side of the equator, Fig. 4, subtract As from AS; but when they are on opposite sides of the equator, Fig. 5, add As and AS—the difference or sum gives the subtense of the stars Ss, it is bisected at right angles in D. Then $\frac{Ss+As}{2}$, Fig. 4, or $\frac{Ss-As}{2}$, Fig. 5, = AD. In the right-angled triangle ADN, are given angle A and side AD to find the hypotenuse AN. The point N is therefore known the node of the vertical. From the same data its angle with the equator is found. From the above rules the table of 8 pairs of stars for equal altitudes has been constructed.

V. Abbreviations where there is not room for the whole word,—N. North, S. South, E. East, W. West, R.A. Right Ascension, Dec. Declinations, N. Hem. Northern Hemisphere, S. Hem. Southern Hemisphere, U. Tran. Upper Transit, L. Tran. Lower Transit.

VI. The Upper and Lower Transit so marked here may not always be those at Greenwich, but such at the place of observation.

In the vertical columns of the tables, there are three columns for each pair of stars; the left hand column generally for the northern hemisphere, and the right hand column for the southern, showing the right ascension of the vertical circle at every five degrees of latitude. The middle column shows the angle of intersection of the vertical with the meridian at that latitude. The marks at the head of the columns E of N, &c., show whether the vertical is east or west of the meridian, for all meridians east of north, when observing northward, is the same as west of south, observing southward.

VII. To ascertain when and where the phenomena are to be found.

To the time at the place by account, add the right ascension of the sun (page II. of the month), if the sum exceeds 24^h., subtract 24 from it, the sum, or remainder, gives the approximate right ascension of the zenith of the place of observation. Then in any or all of the two following tables, and in any of the vertical columns headed for the hemisphere of the place, and in the horizontal line with the nearest latitude by account, all the quantities of right ascension that are greater than that of the zenith, as above stated, are available for observation. Those whose right ascensions are less, the time is past for them. It will be found that in an average of cases there will be about six opportunities during the night, before daylight approaches, if the sky remains clear. The difference of the right ascension of the zenith, and that given in the tables, is the time that will elapse before the stars come into position. In the middle column, the angle made by the vertical circle and the meridian, in the line also with latitude, shows the direction east or west by compass where the stars are to be seen. Whether the observer knows the stars or not, he need make no mistake, for, in the direction pointed out, he will there see the two bright stars about to come into the vertical position, or it points out the middle of the two horizontal stars. The right ascension and declination of the stars given in the table, compared with the latitude, will show whether they are north or south, and will also give a notion of their altitudes within a few degrees; and be it observed, that only one pair of bright stars can be in the same place at the same time. In the constellations of Orion, and the Southern Cross, there might be some difficulty by a number of bright stars being near each other, but a slight study of a map of the stars will point them out. See Art. xvi. Each pair of stars are numbered in the tables from 1 to 16, directly above the names of the stars.

VIII. As the annexed tables are all calculated for the year 1861, the annual variation of the node, given in the horizontal columns, must be multiplied by the number of years after 1861, and the result always added to the time found. There is no parallax, and as altitude is not an element in the problem, there is nothing to do with either refraction or dip of the horizon. In the case of the horizontal stars, even in latitudes where the stars do set, one of the stars may be far below the horizon, and rise again to be serviceable for observation.

PRACTICAL EXAMPLES FROM TABLES 1 & 2.

Example 1.

IX. Suppose February 20, 1861, in Lat. 44° N, Lon. about 41° W, or $2^{h.}$ $44^{m.}$, observed the stars Capella and Rigel (No. 1 in Tables) in a vertical. Required the true time.

	h	m	s
R.A. of Sun, Feb. 20, . .	22	15	35
Lon. 2h. × 9·56 = $19^{s.}$ (Art. xi.)			
$44_{m.}$ = $7_{s.}$			
6 26	+0	0	26
Approximate R.A. of Sun, .	22	16	1

	h	m	s
R.A. of Zenith at 44° lat., .	5	6	33
	+24	0	0
	29	6	33
Approximate R.A. of Sun,	−22	16	1
Approximate Time, ...	6	50	32
$6^{h.}$ × 9·56 = $57^{s.}$			
$50^{m.}$ = $8_{s.}$			
6 $1^{m.}$ $5^{s.}$	−0	1	5
True Time =	6	49	27

In this case the observer will be situated between the two stars, Capella will be a little north of his zenith, and must be the reflected star. The correction for time is subtracted from the approximate time, because it is not known till it is calculated. It is the same whether it is added to the sun's right ascension, or subtracted from the time. In the Table (No. 1) it will be seen that the R.A. of the zenith at 45° is $5^{h.}$ $6^{m.}$ $31^{s.}$, at 40° $5^{h.}$ $6^{m.}$ $43^{s.}$, therefore $2^{s.}$ is added for 44°.

Example 2.

Sept. 22, 1861, in Lat. 39° S, Lon. about 21° or $1^{h.}$ $24^{m.}$ E, observed stars Aldebaran and Pollux having equal altitudes. Required the true time.

	h	m	s
R.A. of Sun, Sept. 22, . .	11	57	56
$2^{h.}$ × $9^{s.}$ = $9^{s.}$ (Art. xi.)			
$24^{m.}$ = $4^{s.}$			
6 13	−0	0	13
Approximate R.A. of Sun, .	11	57	43

	h	m	s
R.A. of Zenith, ...	3	48	58
	+24	0	0
	27	48	58
Approximate R.A. of Sun, .	11	57	43
Approximate Time, . . .	15	51	15
$15^{h.}$ × $9^{s.}$ = $135^{s.}$ }			
50 = $8^{s.}$ } $143^{s.}$	−0	2	23
6			
True Time,	15	48	52

Example 3.

April 11, 1861, in Lat. 50° N, and about $2^{h.}$ $36^{m.}$ W., observed the Pole Star and Spica in a vertical. Required the true time.

	h	m	s
R.A. of Sun, April 11, . .	1	19	45
$2^{h.}$ × $9^{s.}$ = $18^{s.}$			
$36^{m.}$ = $6^{s.}$	+0	0	24
6			
Approximate R.A. of Sun, .	1	20	9

	h	m	s
R.A. of Zenith, ...	13	17	33
Approximate R.A. of Sun,	− 1	20	9
Approximate Time, . . .	11	57	24
$12^{h.}$ × $9^{s.}$ = $108^{s.}$ . .	−0	1	48
True Time,	11	55	36

It will be observed that the above examples, taken from tables 1 and 2, give the time by little more trouble than inspection. As they are all done upon the same principle, any more examples would be unnecessary. It will also be observed that a considerable error in Latitude is of little consequence here; and, in all cases, a whole degree of Longitude causes an error of only two-thirds of a second.

The Tables being calculated for the year 1861, as also the Examples, the annual variation (caused by the precession of the equinoxes), as given in the horizontal columns, must be always added to the time for every year after 1861. For instance, had the last example been calculated for 1865, it would have stood as follows :—

	h	m	s
s years	11	55	36
Add. 3 × 4 =	0	0	12
True Time,	11	55	48

This may be continued to the end of this century, within two seconds of error.

TO DETERMINE THE VARIATION OF THE COMPASS.

X. Direct the Azimuth Compass upon the lower of the two stars, given on Table 1, while they are vertical. The middle column shows the distance, east and west from the Polar meridian. Any practical mariner knows how to accomplish the rest. The observation may be either taken north or south, for east of south is the same as west of north, and the converse.

XI. TABLE

OF THE APPROXIMATE QUANTITIES FOR ONE HOUR OF THE SUN'S RIGHT ASCENSION FOR EVERY TENTH DAY THROUGHOUT THE YEAR.

DATE.		s.	DATE.		s.	DATE.		s.
January,	1	11·03	May,	1	9·54	September,	8	9·01
,,	11	10·84	,,	11	9·78	,,	18	8·98
,,	21	10·55	,,	21	10·01	,,	28	9·03
,,	31	10·21	,,	31	10·21	October,	8	9·17
February,	10	9·88	June,	10	10·35	,,	18	9·38
,,	20	9·56	,,	20	10·40	,,	28	9·67
March,	2	9·33	,,	30	10·35	November,	7	10·01
,,	12	9·17	July,	10	10·17	,,	17	10·36
,,	22	9·07	,,	20	10·00	,,	27	10·69
April,	1	9·09	,,	30	9·76	December,	7	10·95
,,	11	9·18	August,	9	9·58	,,	17	11·08
,,	21	9·33	,,	19	9·29	,,	27	11·12
			,,	29	9·09			

TO CORRECT THE RIGHT ASCENSION OF THE SUN.

Multiply the quantity in line with the nearest date, by the number of hours of time at the place, adding 1 second for every 6 minutes more than the hours. This correction must always be added to the sun's right ascension, given in the "Nautical Almanack," page II. of the month for the same date. The same correction must be made for the hours and minutes of longitude. If the longitude is west, this correction must also be added to the right ascension, but if the longitude is east, it must be subtracted from it.

In the following Tables, in the Vertical columns, the hours of Right Ascension are only once inserted (to save unnecessary space). To all quantities below, the same hour must be applied.

The vertical columns in the Tables give the Right Ascension of the points in the vertical circles for every five degrees of latitude. They have been constructed as follows,—As Tan. of Angle of Node : Tan. of Lat. :: Rad. : Sine of distance from Node. If the stars are east of the Node, that distance is added to the Right Ascension of the Node; but if west, subtracted from it. Time and Right Ascension increase eastward, and decrease westward. The angles given in the middle column are those made by the intersections of the vertical and the meridian at the different latitudes, calculated as follow,—As Cosine of Lat. : Rad. :: Cosine of Angle of Node : Sine of Angle of Intersection.

XII. DESCRIPTION OF AN INSTRUMENT FOR TAKING THE OBSERVATIONS.

This instrument is nothing more than the two reflectors of Hadley's Quadrant, inserted into a brass box, open at top and at both ends. The instrument to be without index, graduated arch or sight hole, but to have a segmental rack and pinion, same as that of a pocket sextant, and the adjusting screws. Fig. 6 shows the position of the instrument and level when adjusted for taking observation on two stars having equal altitudes; the level is guided in its place by the brackets B and C, and held there by the pressure of the screw A. Fig. 7 is a section or view of the various apparatus, N the moveable speculum, O the object glass, R the rack and pinion, and S a spirit level. A small spirit level must be accurately adjusted into a square frame of hard wood or brass. An apparatus of iron or steel (being stronger than brass) must be attached to the box of the instrument, having projecting brackets, so placed and adjusted by filing, that when the spirit level is placed in contact with them it will at once be adjusted in its true place. Fig. 8 shows the position for observing two stars in the same vertical, the level guided in place by the brackets A and D, and kept there by the screw B, while resting upon the edge of the box. It will be observed that A and B act as screws as well as brackets, and that one thumb screw G serves for both, as the level is removed from the one to the other. Fig. 9 is an outline of the instrument without the level, showing the apparatus for holding the level. A, B, C, D are the brackets for holding the level, either horizontally or vertically.

XIII. To Adjust the Apparatus for receiving the Level.

Fix the apparatus to the instrument as nearly correct as can be judged. Then for the vertical stars, suspend a plummet as long as convenient, where there will be no oscillation. Bring the image of the higher part of the line to coincide with the lower part, as by Hadley's Quadrant; then if the bubble of the level is in its true centre, the instrument is so far correct.

For the Horizontal Stars, bring the image of any part of the horizontal line of the sea to coincide with any other part of it; then if the bubble is in its true place, this is also correct. In both cases, however, they may be correct for observing objects near the horizon, and yet not so for elavated objects, unless the level is at right angles to the reflected ray.

To ascertain this, in the first case, bring two separate elevated portions of the plum line to coincide, then if the bubble of the level inclines to a side, that end of the level to which it inclines is too far from the eye, and must be corrected accordingly. For the horizontal stars, a similar observation may be made on two objects of equal altitude, for instance, the two upper corners of a well finished building known to be level, brought to coincide, the observer being placed exactly at equal distance from the corners, then also the end of the level to which the bubble inclines must be brought nearer the eye. These adjustments can be made with a file, for when once adjusted they will remain so, for any length of time, if kept free of accidents. It can be made so strong as not to be easily damaged. Any part of the adjustments cannot alter what has been formerly adjusted, because the filing is done on different brackets, or on different sides of the same bracket. If for the Vertical Stars, fix the spirit level as shown in Fig. 8, the open top of the instrument being held uppermost, then as with Hadley's quadrant, bring the image of the higher star in contact with the lower.

XIV. Method of taking the Observations.

Having selected the two stars to be observed (Art. VII.) at any time before they come into position, for the vertical stars direct the object glass upon the upper star and bring its image down in contact with the lower star as by Hadley's Quadrant, and this being done, do not alter the position of the reflectors, but hold the instrument so that the air bubble may be in its true centre; then if the stars have not yet come into position, the image will be off at a side, or may be altogether out of the field of the instrument, but it will gradually approach till they again come in contact at the due time, and no other but the true star can, for the distances of the stars remain ever the same. When two objects are brought in contact in the quadrant, the reflected ray is always in the plane of the objects. When the instrument is turned out of that plane the objects separate; therefore, when the two stars are seen in contact, while the air bubble is in its true centre, the stars are then in the vertical plane of the observer, and the observation is completed, at which instant the time given by the chronometer must be noted in order to be compared with the local time now found.

XV. FOR THE HORIZONTAL STARS.

The level must be fixed as shown in Figs. 6 and 8, the open top of the instrument turned into the plane of the two stars. Bring the image of one of the stars in contact with the other, then if the stars are not yet into the horizontal position, the image will be above or below the other stars when the bubble is in its centre. In this case also, when the stars are in contact simultaneously with the bubble being in its centre, the observation is finished, the observer being then in the vertical plane which bisects the distance of the stars at right angles, and the time must be noted accordingly. In all cases, the objects must be brought in contact, in or near the junction of the clear and mirror parts of the object glass. The observer need not exert his attention until the stars are about to come into position.

XVI. Another appendage to the instrument (though not absolutely necessary) may be of use. An arch attached to the moveable speculum G, Fig. 7, and graduated to every five degrees, to move along with the speculum towards N, and show the degrees pointed out by the fixed line M. In the tables are given the subtense or distances of each pair of stars. Let the speculum be moved until the degrees given in the table cut the fixed line M, in a rough way; then when the instrument is directed upon the direct star, the image of the other star will appear in the field of the object glass, and can be adjusted into the true contact. This serves as a proof that the true stars have been taken.

The spirit level to be used should not be so sensitive as those used on land for taking levels within an inch to a mile. Such exactness cannot be expected at sea. The tube of the level should be a segment of about 30-inch radius, the bubble moving about half an inch to a degree. In making the observation, the level and the objects are seen both at once in the same line of vision. In dark nights, when there is no moon, the same lantern that shows the chronometer will also show the level.

This instrument has been tested at sea. Its degree of accuracy depends upon circumstances. It must be in hands of ordinary steadiness. Any mariner that can steady his telescope upon an object in the ordinary way will have no difficulty in this. Its accuracy is also, as the largeness of the ship directly, and the roughness of the sea inversely. It is not adaped for row boats except in a calm, nor for very small vessels except in moderate weather; but such are generally employed on short voyages and do not need it.

It may therefore be observed, that in favourable circumstances, the slight wavering of the level being scarcely visible, the observation may approach indefinitely near to exactness. In the most extreme case, with care and attention, the error need not exceed 20s. or 5′. In storms, advantage may be taken of a momentary lull; a second of time is sufficient to show the progress of the stars. When the slight waverings of the level are seen about equal on each side of its centre, while at the same time the slight waverings of the reflected star are equal on each side of the direct star, the observation is finished.

As in the use of any instrument, or in any manipulation however simple, so in this, some practice leads to expertness.

It may be observed here, that the apparatus for receiving the spirit level can be attached to Hadley's quadrant, without in the least impairing it for its other purposes. Observations can be taken with the instrument on stars on opposite sides of the zenith, and to 120 degrees of distance.

On land, a small plummet is sufficient for taking the observations, but the stars must both be on the same side of the zenith, and the vertical stars only. The same may be used at sea on smooth water, the plummet being submerged in a bucket of water to check oscillation.

TABLE I.—For Finding the Time by Inspection with Stars in the same Vertical.

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 1.		
Capella	5 6 26	45 51 7
Rigel	5 7 51	8 21 55S
R.A. of Node	5 7 47	
Angle with Equator		89 54 34
Annual Var. of Node	+2·7	
Subtense		54 13 0
No. 2.		
α Ursæ Minor Pole Star	1 8 21	88 34 7N
α Ursæ Major Near Pointer	10 55 7	62 30 1N
R.A. of Node	11 0 56	
Angle of Node		89 14 46
Annual Var. of Node	−1·17	
Subtense		26 4 0
No. 3.		
Pole Star	1 8 21	88 34 7N
α Cassiopeæ	0 32 33	55 46 28N
R.A. of Node	0 31 18	
Angle of Node		89 45 51
Annual Var. of Node	+3	
Subtense		32 48 0
No. 4.		
Pole Star	1 8 21	88 34 7N
Spica	13 17 52	10 26 5S
R.A. of Node	13 17 49	
Angle		89 56 15
Annual Var. of Node	+3·0	
N. Hemisphere only		
Subtense		10 1 52

Lat.	No. 1. N. Hem. Angle W. of N.	No. 1. Angle with M.	No. 1. S. Hem. Angle E. of S.	No. 2. U. Tran. Angle W. of N.	No. 2. Angle.	No. 2. L. Tran. Angle E. of N.	No. 3. U. Tran. Angle E. of N.	No. 3. Angle.	No. 3. L. Tran. Angle W. of N.	No. 4. N. Hem. Angle W. of N.	No. 4. Angle.	No. 4. S. Hem.
	5 hours. m s	° ′	5 hours. m s	11 hours m s	° ′	23 hours m s	0 hours. m s	° ′	12 hours m s	13 hours m s	° ′	13 hours m s
0	7 47	0 6	7 47	0 56	0 45	0 56	31 18	0 14	31 18	17 49	0 4	17 49
5	7 46	0 6	7 48	0 40	0 45		31 23	0 14		17 48	0 4	
10	7 44	0 6	7 50	0 24	0 46		31 28	0 14		17 47	0 4	
15	7 42	0 6	7 52	0 7	0 47		31 33	0 15		17 46	0 4	
20	7 40	0 6	7 54	10h–10s	0 48		31 39	0 15		17 45	0 4	
25	7 38	0 6	7 56	59 32	0 50		31 44	0 16		17 43	0 4	
30	7 35	0 7	7 59	59 10	0 52	2 42	31 50	0 16		17 42	0 5	
35	7 31	0 7	8 3	58 49	0 55	3 3	31 57	0 17	30 39	17 40	0 5	
40	7 28	0 7	8 6	58 23	0 59	3 29	32 5	0 18	30 31	17 38	0 5	
45	7 25	0 8	8 9	57 54	1 5	3 58	32 14	0 20	30 22	17 36	0 6	
50	7 21	0 8		57 20	1 12	4 32	32 24	0 22	30 12	17 33	0 6	
55	7 16	0 9		56 37	1 19	5 15	32 36	0 25	30 0	17 30	0 7	
60	7 10	0 11		55 42	1 33	6 10	32 52	0 29	29 44	17 27	0 8	
65	7 0	0 13		54 27	1 47	7 25	33 16	0 34	29 20	17 23	0 9	
70	6 43	0 16		52 40	2 12	9 12	33 56	0 41	28 40	17 16	0 11	
75	6 28	0 21		49 40	2 55	12 12	34 47	0 55	27 47	16 53	0 14	

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 5.		
β Hydri	0 18 23	78 2 17S
α^1 Crucis	12 18 53	62 19 39S
R.A. of Node	0 19 8	
Angle		89 58 0
Annual Var. of Node	+2·8	
S. Hemisphere only		
Subtense		39 40 0
No. 6.		
β Tauri	5 17 30	28 29 9N
γ Orion	5 17 39	6 13 18N
R.A. of Node	5 17 45	
Angle		89 53 0
Annual Var. of Node	+3·3	
Subtense		22 16 0
No. 7.		
α Pegasi (*Markab*)	22 57 50	14 27 29N
β Pegasi	22 57 3	27 19 41N
R.A. of Node	22 58 37	
Angle		89 14 36
Annual Var. of Node	+3	
Subtense		12 52 0
No. 8.		
α Can. Min. (*Procyon*)	7 32 1	5 34 42N
Pollux	7 36 48	28 21 30N
R.A. of Node	7 30 58	
Angle		87 18 30
Annual Var. of Node	+3·4	
Subtense		22 47 0

Lat.	No. 5. U. Tran. Angle W. of S.	No. 5. Angle.	No. 5. L. Tran. Angle E. of S.	No. 6. N. Hem. Angle W. of N.	No. 6. Angle.	No. 6. S. Hem. Angle E. of S.	No. 7. N. Hem. Angle W. of N	No. 7. Angle.	No. 7. S. Hem. Angle E. of S.	No. 8. N. Hem. Angle E. of N.	No. 8. Angle.	No. 8. S. Hem. Angle W. of S.
	0 hours. m s	° ′	12 hours m s	5 hours. m s	° ′	5 hours. m s	22 hours m s	° ′	22 hours m s	7 hours. m s	° ′	7 hours. m s
0	19 8	0 2	19 8	17 45	0 7	17 45	58 37	0 45	58 37	30 58	2 42	30 58
5	19 7	0 2		17 43	0 7	17 47	58 21	0 45	58 53	31 55	2 43	30 2
10	19 6	0 2		17 40	0 7	17 50	58 5	0 46	59 9	32 52	2 45	29 4
15	19 5	0 2		17 37	0 7	17 53	57 49	0 47	59 25	33 52	2 47	28 4
20	19 4	0 2		17 35	0 7	17 55	57 32	0 48	59 42	34 52	2 52	27 1
25	19 3	0 2		17 32	0 8	17 58	57 13	0 50	23h 1s	35 59	2 58	25 54
30	19 2	0 2	19 14	17 29	0 8	18 1	56 54	0 52	0 20	37 13	3 6	24 43
35	19 1	0 3	19 15	17 25	0 8	18 5	56 34	0 55	0 40	38 31	3 17	23 25
40	18 59	0 3	19 17	17 21	0 9	18 9	56 5	0 59	1 7	40 2	3 31	21 54
45	18 58	0 3	19 18	17 16	0 10	18 15	55 35	1 5	1 39	41 47	3 48	20 9
50	18 56	0 3	19 20	17 11	0 11	18 20	55 1	1 11	2 13	43 51	4 11	18 5
55	18 54	0 4	19 22	17 4	0 12	18 27	54 20	1 21	2 54	46 26	4 42	15 30
60	18 51	0 4	19 25	16 56	0 14	18 35	53 23	1 33	3 51	49 42	5 31	12 14
65	18 47	0 5	19 29	16 45	0 16	18 46	52 7	1 47		54 10	6 22	
70	18 42	0 6	19 34	16 28	0 20	19 1	50 23	2 12		8h 46s	7 53	

TABLE II.—For Finding the Time by Inspection with Stars having Equal Altitudes.

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 9.		
α Andromedæ	0 1 12	28 19 23N
Pollux	7 36 48	28 21 30N
R.A. of Node . . .	3 48 50	
Angle		89 59 19
Annual Var. of Node	+3.4	
Subtense . . .		90 26 0

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 10.		
α Andromedæ	0 1 12	28 19 23N
β Tauri	5 17 30	28 29 9N
R.A. of Node . . .	2 39 7	
Angle		88 49 56
Annual Var. of Node	+3·4	
Subtense . . .		59 44 0

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 11.		
Rigel	5 7 51	8 21 55S
α Hydræ	9 20 45	8 3 29S
R.A. of Node . . .	7 13 57	
Angle		89 20 42
Annual Var. of Node	+2·9	
Subtense . . .		62 3 0

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 12.		
β Tauri	5 17 30	28 29 9N
Pollux	7 36 48	28 21 30N
R.A. of Node . . .	6 26 16	
Angle		89 48 52
Annual Var. of Node	+3·7	
Subtense . . .		80 10 0

Lat.	N. Hem. Angle W. of N.	Angle.	S. Hem. Angle E. of S.	N. Hem. Angle W. of N.	Angle.	S. Hem. Angle E. of S.	N. Hem. Angle W. of N.	Angle.	S. Hem. Angle E. of S.	N. Hem. Angle W. of N.	Angle.	S. Hem. Angle E. of S.
	3 hours. m s	° ′	3 hours. m s	2 hours. m s	° ′	2 hours. m s	7 hours. m s	° ′	7 hours. m s	6 hours. m s	° ′	6 hours. m s
0	48 50	0 1	48 50	39 7	1 10	39 7	13 57	0 39	13 57	26 16	0 11	26 16
5	48 50	0 1	48 50	39 4	1 11	39 11	13 45	0 39	14 49	26 13	0 11	26 20
10	48 49	0 1	48 51	39 0	1 12	39 15	13 31	0 40	14 23	26 9	0 11	26 23
15	48 48	0 1	48 52	38 57	1 13	39 19	13 16	0 41	14 38	26 4	0 12	26 28
20	48 47	0 1	48 53	38 53	1 15	39 23	12 59	0 42	14 55	26 0	0 12	26 32
25	48 46	0 1	48 54	38 48	1 17	39 28	12 44	0 44	15 14	25 55	0 12	26 37
30	48 45	0 1	48 55	38 43	1 20	39 33	12 25	0 46	15 33	25 50	0 13	26 42
35	48 44	0 1	48 56	38 38	1 25	39 38	12 6	0 48	15 52	25 45	0 13	27 47
40	48 42	0 1	48 58	38 32	1 31	39 44	11 44	0 51	16 14	25 39	0 14	27 53
45	48 40	0 1	49 0	38 26	1 39	39 50	11 18	0 56	16 40	25 32	0 15	28 0
50	48 38	0 2	49 2	38 18	1 49	39 58	10 47	1 1	17 11	25 23	1 17	28 9
55	48 36	0 2	49 4	38 7	2 6	40 8	10 10	1 9	17 48	25 13	1 19	28 19
60	48 34	0 2	49 6	37 53	2 24	40 21	9 23	1 20	18 35	24 59	1 22	28 33
65	48 32	0 2		37 37	2 46		8 16	1 32	19 42	24 41	1 26	
70	48 29	0 3		37 13	3 24		6 40	1 54	21 18	24 15	1 33	

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 13.		
Castor	7 25 44	32 11 22N
ι Aurigæ	4 47 57	32 56 31N
R.A. of Node . . .	6 3 36	
Angle		88 49 30
Annual Var. of Node	+3.88	
Subtense . . .		32 25 0

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 14.		
Regulus	10 0 38	12 38 42N
α Ophiuchi	17 28 29	12 39 51N
R.A. of Node . . .	13 44 43	
Angle		89 58 45
Annual Var. of Node	+3	
Subtense . . .		103 12 0

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 15.		
12 Canum Venaticor	12 49 31	39 4 11N
α Lyræ (*Vega*) . .	18 32 14	38 39 23N
R.A. of Node . . .	15 40 9	
Angle		89 26 38
Annual Var. of Node	+2·4	
Subtense . . .		51 0 0

Names of Stars.	R.A. h m s	Dec. ° ′ ″
No. 16.		
α Eridani	1 32 32	57 56 37S
ι Argûs	9 13 22	58 41 33S
R.A. of Node . . .	5 24 28	
Angle		89 31 49
Annual Var. of Node	+2	
R.A. of Node, L Tran.	17 24 28	
Subtense . . .		52 40 0

Lat.	N. Hem. Angle E. of N.	Angle.	S. Hem. Angle W. of S.	N. Hem. Angle W. of N.	Angle.	S. Hem. Angle E. of S.	N. Hem. Angle E. of N.	Angle.	S. Hem. Angle W. of S.	N. Hem. Angle W. of N.	Angle.	S. Hem. Angle E. of S.
	6 hours. m s	° ′	6 hours. m s	13 hours m s	° ′	13 hours m s	15 hours m s	° ′	15 hours m s	5 hours. m s	° ′	5 hours. m s
0	3 36	1 10	3 36	44 43	0 1	44 43	40 9	0 33	40 9	24 28	0 28	24 28
5	4 0	1 11	3 12	44 43	0 1	44 43	40 20	0 34	39 58	24 20	0 28	24 36
10	4 25	1 12	2 47	44 42	0 1	44 44	40 32	0 34	39 46	24 12	0 28	24 44
15	4 51	1 13	2 21	44 42	0 1	44 44	40 46	0 35	39 32	24 3	0 29	24 53
20	5 19	1 15	1 53	44 41	0 1	44 45	40 58	0 36	39 19	23 54	0 30	25 2
25	5 47	1 17	1 25	44 40	0 1	44 46	41 13	0 38	39 5	23 44	0 31	25 12
										S. Hem. W. of S.		
30	6 19	1 20	0 53	44 39	0 2	44 47	41 28	0 39	38 50	17h23m33s	0 33	25 25
35	6 54	1 25	0 18	44 38	0 2	44 48	41 43	0 41	38 35	23 21	0 35	25 37
40	7 31	1 32	5h 19s	44 37	0 2	44 49	42 3	0 43	38 15	23 8	0 37	25 50
45	8 18	1 40	58 54	44 36	0 2	44 50	42 24	0 47	37 54	22 54	0 40	26 4
50	9 12	1 50	58 0	44 35	0 2	44 51	42 50	0 52	37 28	22 35	0 44	26 22
55	10 19	2 7	56 53	44 34	0 2	44 52	43 21	0 59		22 16	0 50	26 42
60	11 44	2 25	55 28	44 32	0 2	44 54	44 1	1 8		21 44	0 58	27 14
65	13 41	2 47		44 29	0 3	44 57	44 59	1 19		21 4	1 7	27 54
70	16 32	3 26		44 25	0 3	45 1	46 16	1 38		20 8	1 22	28 58

Fig. 1.

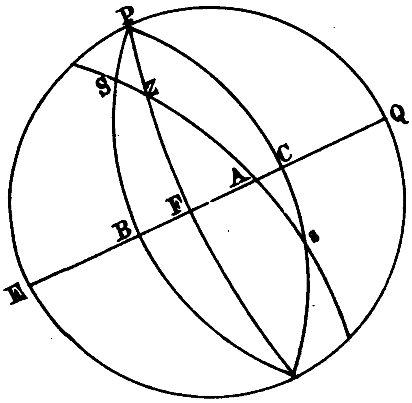
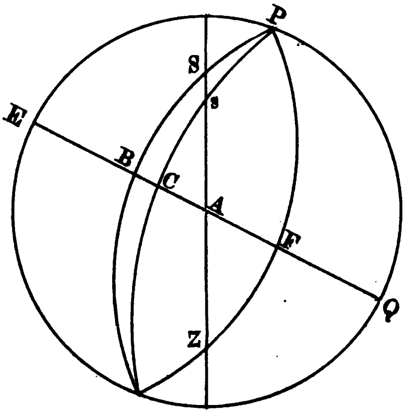


Fig. 2.



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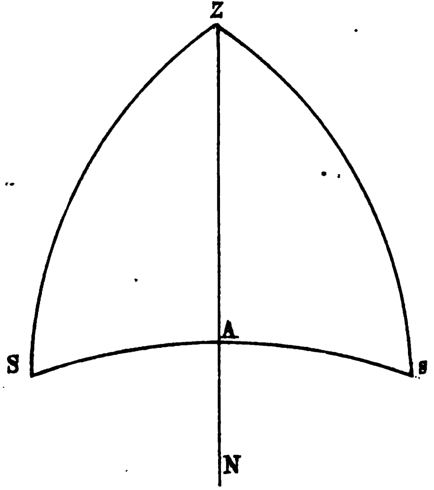

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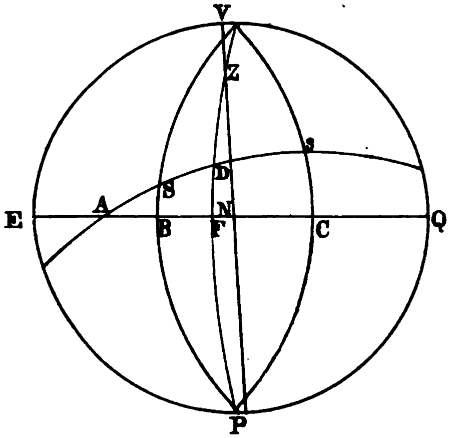

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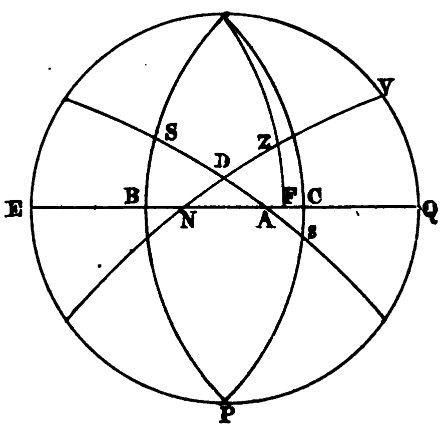

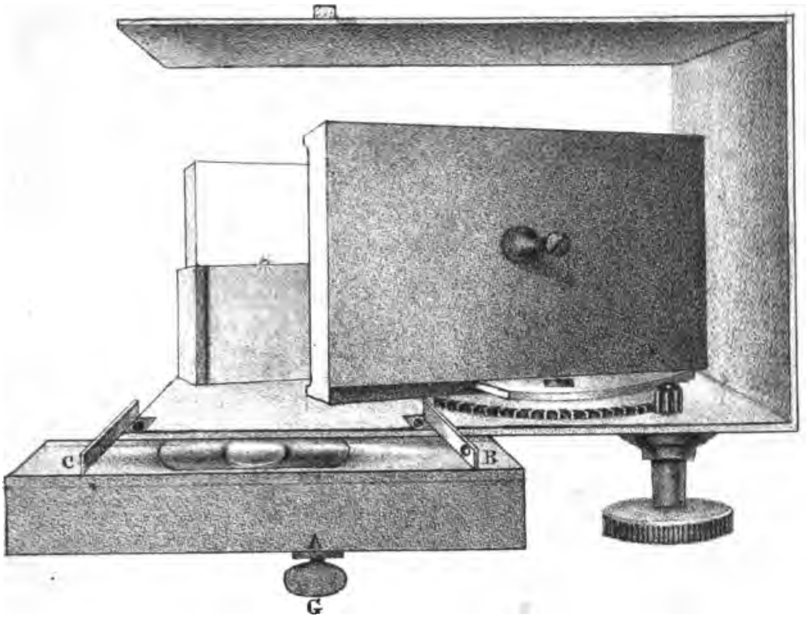

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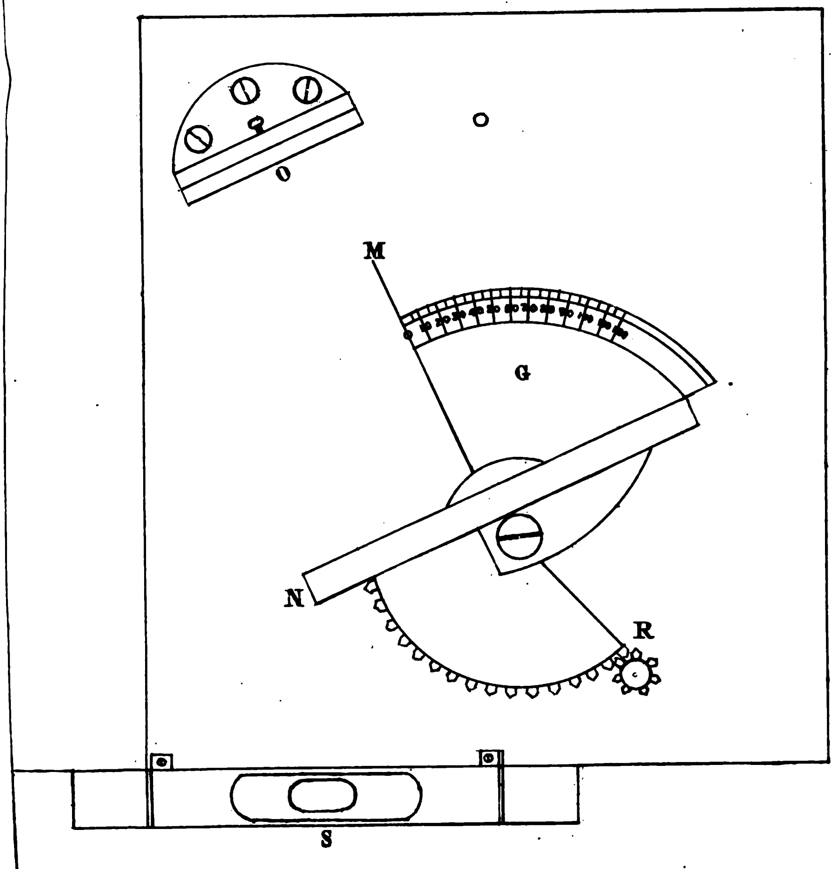

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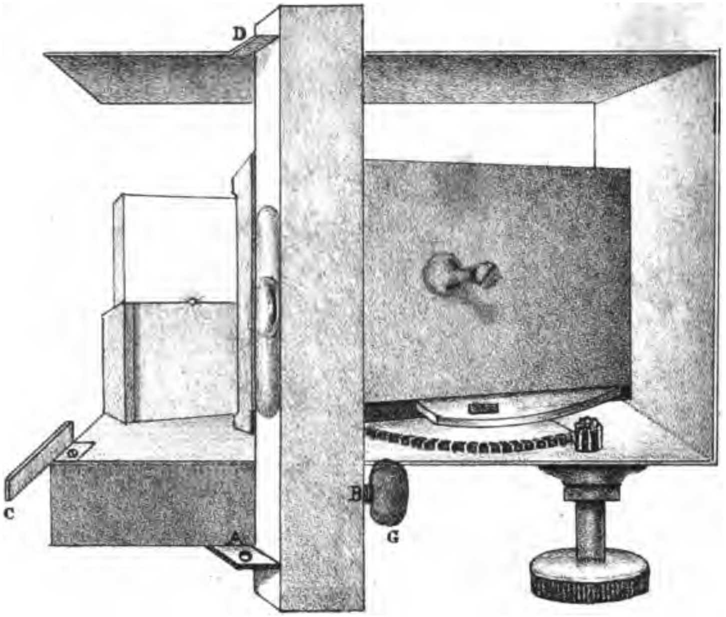

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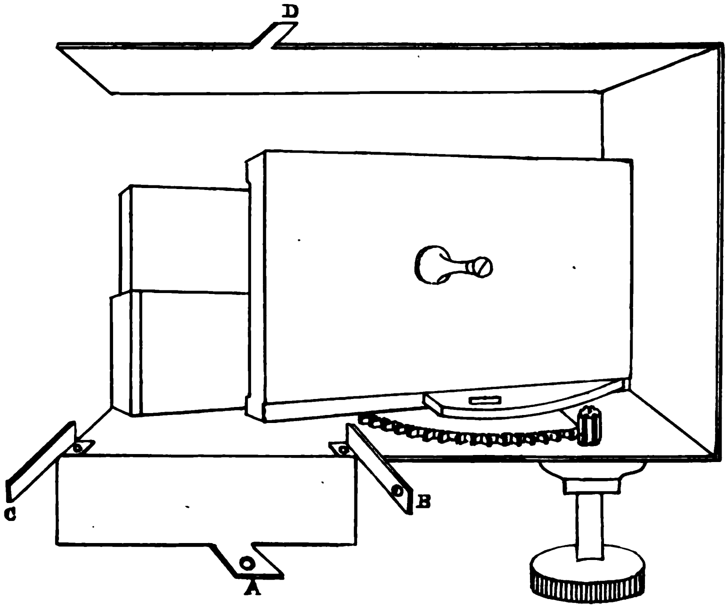

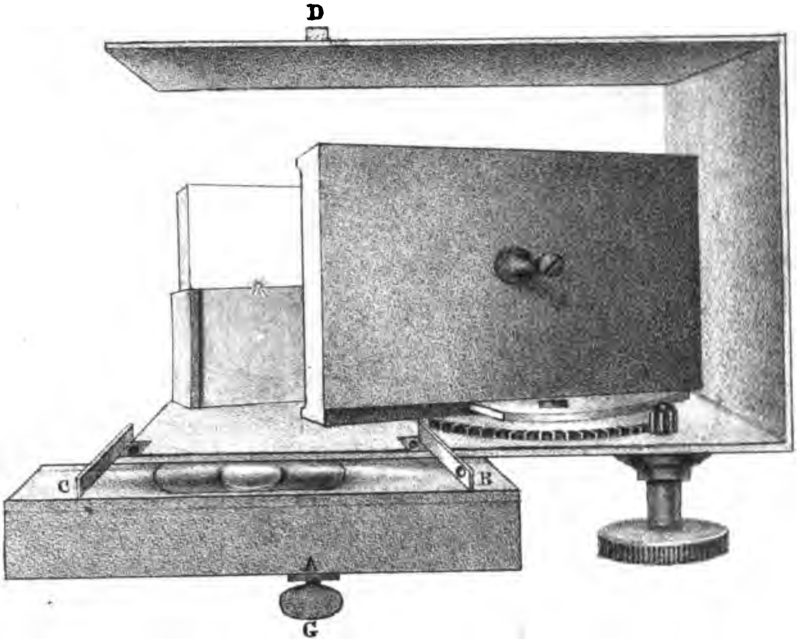

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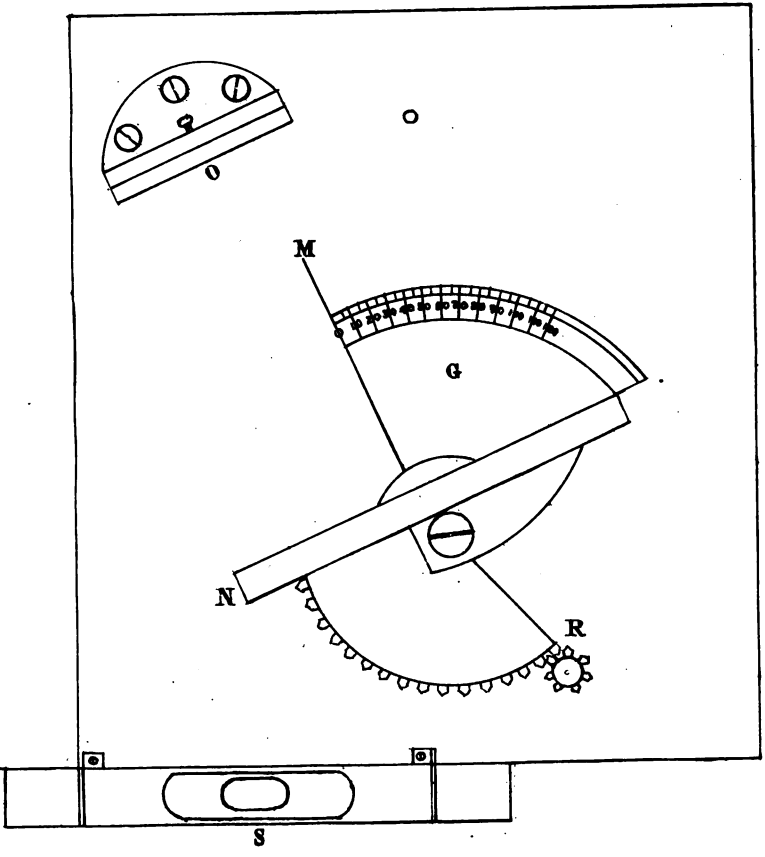

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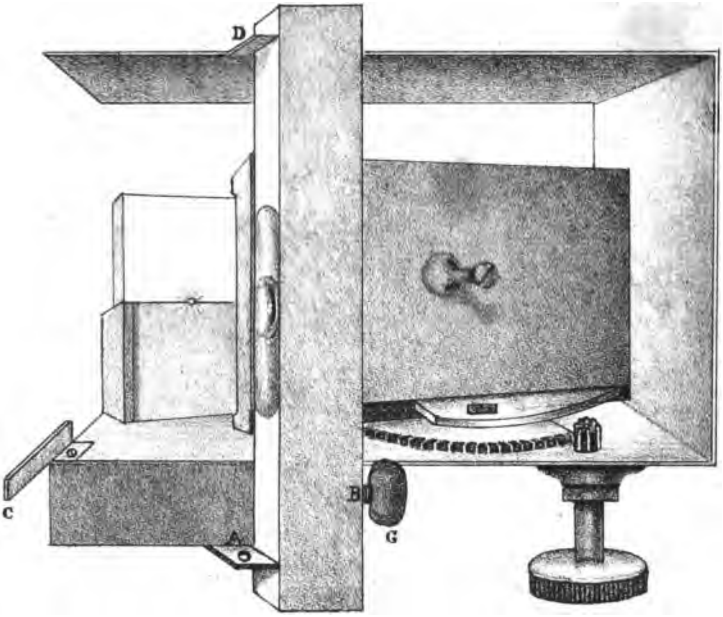

Fig 9.